Rethinking contact lens aftercare

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Rethinking contact lens aftercare

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ABSTRACT

The evolution of contact lens technology and clinical practice over the past three decades has been remarkable, with dramatic improvements in material biocompatibility, better lens designs and care systems and more flexible and convenient modalities of wear. However, our approach to the aftercare examination has remained conservative, with the general *modus operandi* having not fully evolved from the difficult, early years of fitting non-regular replacement rigid and low water content hydrogel lenses. In this paper, we review current aftercare practice and in particular, the preferred frequency that lens wearers should return for routine visits and the appropriateness of regulations governing contact lens prescription expiry. Four key clinical reasons for conducting a routine aftercare visit are identified – preserving ocular health, maintaining good vision, optimizing comfort and ensuring satisfactory lens fitting performance. Commercial reasons for conducting aftercare visits are also considered. A decision matrix is presented to help practitioners decide upon appropriate time interval between routine aftercare visits. The first aftercare visit should always take place within 1-2 weeks of lens dispensing. After this, the following time intervals between routine aftercare visits are advised as a general guideline: soft daily disposable, 24m; soft daily reusable and rigid daily wear, 12m; soft and rigid extended wear, 6m. These aftercare visit frequencies may need to be adjusted when rapid rates of refractive change are anticipated, such as every 6m during child/teenager myopia and every 12m during presbyopia. The numerous clinical caveats for varying these recommended aftercare frequencies are also discussed. Those new to lens wear should be seen within the first 2m of lens dispensing. Regulatory authorities charged with the responsibility of stipulating the validity of a contact lens prescription should continue to allow optometrists to set an expiry date relevant to the circumstances of individual lens wearers.
Key Words: aftercare, comfort, commercial considerations, compliance, complications, contact lens, drop-out, lens fitting performance, ocular health, product advice, vision, visit frequency
The provision of safe and efficient health care requires constant updating and revision, as the scientific principles underlying clinical practice evolve and new methods and techniques are developed. Contact lens practice is a good example of a fast-moving health care field; the ongoing development of alternative modes of refractive correction and control, and of lens materials, designs, replacement frequencies and modalities of wear, means that the mode of practice a decade ago may not be entirely relevant today.

Follow-up examinations represent a fundamental aspect of health care, especially when managing ongoing or chronic conditions. In this context, contact lens wear can be considered as a health care modality that requires ongoing management. The aftercare examination is therefore an important cornerstone of contact lens practice, the approach to which needs to be kept under constant review.¹

The purpose of this paper² is to rethink contact lens aftercare in a modern context. We will explore two overarching issues – the key reasons for conducting aftercare examinations and the appropriate frequency for aftercare visits. Although many of the issues discussed here relate to all genres of eye care practitioner, our discussion will focus on the aftercare examination in optometric practice because of the unique characteristics of this profession, such as the often commercial practice setting³ and lens wearer demographics.³

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¹ This paper is based on a lecture presented by Professor Nathan Efron to the Cornea and Contact Lens Society of Australia at the 15th International Cornea and Contact Lens Congress, Gold Coast, Queensland, Australia on May 23, 2105, on the occasion of him being awarded the Kenneth W Bell Medal.
FREQUENCY OF AFTERCARE VISITS

When recommending a time frame for routine follow-up evaluations, optometrists must strive to strike a balance between (a) having the lens wearer come back frequently enough to enable early detection and successful management of any adverse circumstances that may be developing, versus (b) not unduly inconveniencing lens wearers.

Experience of dentistry

The question of an appropriate interval between routine aftercare visits is not unique to optometry. Dentistry is a profession that has some parallels with contact lens practice, in terms of practice setting, access to the public, and the requirement for routine check-ups. Although recommendations regarding optimal dental recall intervals vary between countries and dental healthcare systems, six-monthly dental check-ups traditionally have been advocated by general dental practitioners in many developed countries.\textsuperscript{4,5}

A Cochrane review in 2013\textsuperscript{4} sought to find evidence in the literature to support recall intervals of any duration for dental patients. The review concluded that there was a very low quality body of evidence from one randomised clinical trial, which was deemed insufficient to draw any conclusions regarding the potential beneficial or harmful effects of altering the recall interval between dental check-ups. No evidence was found to support or refute the traditional practice of encouraging attendance for dental check-ups at six-monthly intervals. The review authors stated that it was important that high quality randomised clinical trials be conducted to determine the optimum frequency for dental review.\textsuperscript{4}

As is the case in respect of dentistry, there is no evidence underpinning an appropriate or recommended aftercare frequency for contact lens wearers.
Historical perspective

A cautious approach to the frequency of contact lens aftercare visits is reflected in journal articles and contact lens textbooks published soon after the introduction of soft contact lenses into the world market in 1972.

United States

In a clinical article entitled ‘Aftercare of soft contact lenses’ published in 1976, Kennedy advised that, following lens fitting, soft lens wearers should be examined “… at the end of one month, three months then six months … sooner if problems.”

In the first textbook account of soft lenses published in the United States, in 1981, Mandell recommended an aftercare schedule after initial lens fitting of three days, one week, two weeks, one month, then every six months.

United Kingdom

The first textbook description of soft contact lenses published in the United Kingdom was ‘Contact Lenses’ by Stone and Phillips. The following recommendation was made: “The practitioner must lay great emphasis on the need for regular after-care visits after the initial supervised period. These may be carried out at 9 or 12 month intervals.”

Reasons for the early cautious approach

This cautious approach to aftercare visits in the early days of soft lenses stemmed in part from previous experiences with rigid lenses, which required numerous follow-up consultations after the lenses were dispensed to refine the lens fit (by lens
polishing/modification or reordering a new lens), ensure the proper adaptation to lens wear, and monitor common adverse reactions such as central corneal clouding (excess oedema) and 3 and 9 o’clock corneal staining.

There were perhaps other good reasons for recommending such a cautious approach in respect of soft lenses: they were a new vision correction paradigm and little was known of their long-term physiological impact. Reports soon emerged of high levels of corneal oedema due to the low oxygen transmissibility of the hydroxyethyl methacrylate material from which most of the early soft lenses were fabricated. Previously unseen ocular complications of lens wear were being discovered on a regular basis. Soft lenses were only replaced when they could no longer be comfortably worn, often due to a build-up of lens deposits which could not be completely removed by cleaning solutions (Figure 1). Understandably, all of these factors demanded a conservative approach to the management of contact lens wearers, including frequent aftercare visits after lenses were dispensed.

**Current advice**

Whatever ongoing aftercare visit frequency is advised to a lens wearer, it is considered prudent to conduct an examination within one to two weeks of dispensing the initial lens supply. This will provide an opportunity to ensure that lenses are being handled and worn in accordance with instructions, to verify that lens performance, vision and comfort are in accordance with expectations and to examine the eye for any unexpected early clinical signs or adverse ocular reactions to the lenses or solutions. Current practice is often to only provide enough lenses for the initial wearing period of lens replacement, to provide the lens wearer with additional incentive to return for a check-up and to obtain an ongoing supply of lenses.
During this initial one- to two-week aftercare visit, the lens wearer must be advised how often they need to return for routine aftercare visits. Professional associations seem to offer only general advice in this regard. We conducted an internet search for information on recommended aftercare visit frequency offered by peak professional bodies in Australia, the United Kingdom and the United States. We found that the various bodies offer advice directed towards practitioners, lens wearers, or both.

**Australia**

In a section of its website offering information to the public, Optometry Australia\(^{10}\) notes “Most optometrists encourage contact lens wearers to have eye examinations every 12 months to ensure the prescription and contact lens type are still appropriate and to detect and correct any potential eye problems due to contact lens wear early.”

The Cornea and Contact Lens Society of Australia\(^{11}\) advises lens wearers “Visit your eye doctor once-a-year or more often if needed”.

**United States**

The Optometric Clinical Practice Guideline of the American Optometric Association\(^ {12}\) advises practitioners that “Planned evaluation should occur during the initial weeks and months of contact lens wear …” and “… subsequent evaluations are usually indicated at 6- to 12-month intervals for healthy patients wearing cosmetic contact lenses”. The Guideline goes on to describe situations where more frequent aftercare visits may be required.
**United Kingdom**

In their Guidance for Professional Practice, the College of Optometrists\(^\text{13}\) in the United Kingdom recommends the following: “You should schedule contact lens check-ups according to the patient’s clinical needs. These would normally be every 12 months but may be more or less frequent depending on the type of lens and modality of wear.”

The British Contact Lens Association\(^\text{14}\) advises lens wearers, in respect of aftercare visits: “Routinely the norm is between six to 12 months, however, if you are new to contact lenses or need careful observation then the check-up will be at much shorter intervals.”

The consensus among these peak professional bodies is that aftercare visits should be conducted at a frequency of about every 12 months, but that more or less frequent visits may be more appropriate in certain circumstances.

**Current practice**

It is interesting to compare the above advice with the actual aftercare visit frequency of contact lens wearers. A survey of 222 current and 258 previous contact lens wearers in the United Kingdom found an average self-reported aftercare visit frequency of once every 1.07 years.\(^\text{15}\) As can be seen from Figure 2, a majority of lens wearers (44 per cent) presented annually for a routine aftercare visit, but a significant minority presented every 6 months (33 per cent) or every 2 years (15 per cent).\(^\text{15}\)

**Our approach**

In this review, we will test the varied advice of professional bodies regarding the recommended aftercare visit frequency in the context of four key clinical reasons for
conducting aftercare visits, as discussed in detail below. Although there is considerable overlap of many of the factors discussed, it is helpful to consider each separately in constructing an overall model for contact lens aftercare.

Given that (a) current practice and general advice dictate that contact lens aftercare visits be conducted annually, and (b) soft reusable contact lenses have represented the majority lens type used world-wide for almost half a century, we shall adopt ‘annual reviews for those wearing reusable soft lenses’ as the referent against which all other forms of lens wear will be considered. We will then consider whether higher, lower or matching aftercare frequencies ought to be advised for other lens types, considering the four key reasons for conducting an aftercare visit.

**CLINICAL REASONS FOR AFTERCARE VISITS**

We have identified four clinical reasons for conducting a routine contact lens aftercare examination: (1) preserving ocular health, (2) maintaining good vision, (3) optimizing comfort, and (4) ensuring satisfactory lens fitting performance. Each of these factors shall be considered in turn.

**Preserving ocular health**

It has long been recognised that contact lenses can induce adverse changes in the eyelids, tear film, conjunctiva and all layers of the cornea. Table 1 categorizes key ocular complications of contact lens wear according to whether the conditions are acute or chronic, or have characteristics that are a combination of both. Acute complications of lens wear are typically self-limiting and will often resolve within hours or days following lens removal.
Anticipating ocular complications observed at scheduled aftercare visits

Some lens wearers may make an unscheduled visit to an optometrist to seek advice and treatment for acute complications of lens wear.

Chronic complications of lens wear can be asymptomatic, such as endothelial blebs, or symptomatic, such as papillary conjunctivitis\(^{17}\) (Figure 3). A lens wearer experiencing a mildly symptomatic complication may choose not to take action apart from having the issue reviewed at the next scheduled aftercare appointment. Therefore, at scheduled aftercare visits, practitioners should expect to occasionally observe asymptomatic or mildly symptomatic ocular complications of lens wear.

Contact lens challenges in the 20\(^{th}\) century

There have been significant advances in contact lens technology over the past 30 years that have mitigated against adverse reactions to lens wear. In the mid-1980s, most lenses fitted were made from low water content hydrogel materials,\(^ {18}\) the most popular being hydroxyethyl methacrylate. This material has a very low oxygen permeability (less than 8 x \(10^{11}\) cm\(^2\).mlO\(_2\)/s.ml.mmHg).\(^ {19}\) These lenses were reused until they were too uncomfortable to wear, and sometimes lasted for many years.\(^ {20}\)

Lenses were maintained using either thermal disinfection – which prematurely degraded the lens polymer – or an assortment of chemicals, such as surfactant cleaners, disinfecting solutions, protein removal systems and wetting agents, which were of marginal ocular biocompatibility. As well, lens wearers were often advised that they could sleep in these lenses. As a consequence of the above practices, complications such as lens-induced hypoxia, adverse solution reactions, physical trauma from coated and damaged lenses, and high rates...
of infiltrative events,$^{17}$ needed to be resolved at aftercare visits, which necessarily had to be scheduled frequently, at six to 12 month intervals.

**Contact lens advances in the 21st century**

Compare the scenario outlined above with contact lens practice today. Virtually all soft lenses are now replaced at least monthly (Figure 4), so long term deposition and lens degradation are no longer relevant. Over the past 17 years there has been a substantial increase in the use of high oxygen performance silicone hydrogel lenses around the world such that they now constitute the majority of lenses prescribed today$^{21}$ (Figure 5). Silicone hydrogel materials have a far greater oxygen permeability (greater than 60 x $10^{11}$ cm$^2$.mlO$_2$/s.ml.mmHg) than conventional hydrogel materials (less than 40 x $10^{11}$ cm$^2$.mlO$_2$/s.ml.mmHg) (Figure 6). Hypoxic complications of lens wear are largely obviated in those wearing silicone hydrogel lenses. Daily disposable lenses are increasing in popularity, as demonstrated in Figure 7;$^{16}$ the wearing of such lenses eliminates adverse reactions to contact lens solutions.

**Epidemiology of contact lens-induced adverse events**

A useful method for addressing the underlying question posed in this review – the desired frequency routine aftercare visits for contact lens wearers – is to examine the rate of adverse events, as revealed by clinical trials and epidemiological studies, in respect of lens material, solution usage, replacement frequency and wearing modality. Most studies conducted over the past two decades use corneal infiltrative events and microbial keratitis as the primary measures of adverse ocular reactions to contact lens wear.
Silicone hydrogel lenses
Silicone hydrogel contact lenses were developed to alleviate hypoxic complications of lens wear and studies have since confirmed this to be the case.\textsuperscript{22} Thus, the ocular complications highlighted in bold font in Table 1, which have a hypoxic aetiology, are seldom seen in those wearing silicone hydrogel lenses. However, silicone hydrogel lenses have not resulted in a decrease in the rate of occurrence of infiltrative events or microbial keratitis compared with hydrogel lenses.\textsuperscript{23, 24} The lower rate of infiltrative events observed among hydrogel lens wearers has been attributed to the protective effect of lysozyme,\textsuperscript{25} which deposits much more readily on hydrogel lenses than silicone hydrogel lenses.

Daily disposable lenses
Daily disposable lenses are associated with a 12.5 X lower risk of corneal infiltrative events compared with reusable lenses.\textsuperscript{26} By interrogating a large post-market surveillance registry, Chalmers and colleagues\textsuperscript{27} found a very low annualised rate of corneal infiltrative events of 0.4\% in those wearing silicone hydrogel daily disposable lenses, and an absence of such observations in hydrogel daily disposable lenses. This compares favourably with annualised rates about 4\% in those wearing reusable silicone hydrogel lenses.\textsuperscript{28}

In addition to the low rate of corneal infiltrative events with daily disposable lenses, Morgan and colleagues\textsuperscript{29} reported that bulbar conjunctival hyperaemia, limbal hyperaemia, corneal staining, conjunctival staining and papillary conjunctivitis were clinically equivalent between a group of subjects wearing this lens type in a silicone hydrogel material versus a group of subjects who did not wear contact lenses. Studies such as these establish daily disposability lenses as an intrinsically safe form of lens wear.
The 12.5X greater risk of developing corneal infiltrative events with reusable lenses versus daily disposable lenses\textsuperscript{26} may be attributed, in part, to the use of contact lens solutions. Certainly, various combinations of silicone hydrogel lenses and solutions containing polyhexadine and polyquaternium:1 are known to be associated with increased rates corneal staining compared with the use of silicone hydrogel lenses with a hydrogen peroxide disinfected solution, which neutralises to become an innocuous saline solution following the disinfection procedure.\textsuperscript{30}

**Overnight lens wear**

It has long been recognised that sleeping in contact lenses carries a 5X greater risk of microbial keratitis compared with daily wear of lenses. This relative risk factor was originally demonstrated by Schein and colleagues\textsuperscript{31} in 1989, in the era of hydrogel lenses. Subsequent epidemiological studies reported similar findings with hydrogel lenses in 1999\textsuperscript{32} and with both hydrogel and silicone hydrogel lenses in 2005\textsuperscript{23} and 2008.\textsuperscript{24}

Notwithstanding the greater risk of microbial keratitis associated with extended wear versus daily wear of soft lenses, when put in perspective with other life and ophthalmic risks, such occurrences are relatively rare.\textsuperscript{33} For example, Szczotka-Flynn and colleagues.\textsuperscript{33} point out that the risk of silicone hydrogel lens-related microbial keratitis about the same as the risk of developing breast cancer; 7 times less than proceeding to penetrating keratoplasty in keratoconus; and 20 time less than developing nuclear cataract. In this context, some patients with added vocational and avocational demands may take the reasonable view that the benefits of extended wear outweigh the low risks of developing microbial keratitis.
Unfortunately, the public perception of the risk of microbial keratitis associated with lens wear in general has been repeatedly and disproportionately inflated by non-contextual reporting in the ophthalmic literature and sensationalist journalism in the lay press.

Rigid lenses

Rigid lens wear is often associated with three intractable and potentially serious complications – corneal warpage, 3 and 9 o’clock corneal staining and eyelid ptosis.\textsuperscript{17,34} On the other hand, rigid lens wear is associated with a relatively low risk of microbial keratitis.\textsuperscript{23,24}

The role of compliance in maintaining ocular health

Given the above analysis, soft lens types can be broadly categorized into three types with an increasing likelihood of the risk of an adverse event (and in particular a corneal infiltrative event or microbial keratitis): daily wear disposables, daily wear reusable lenses and extended wear lenses. As described earlier, the frequency of an aftercare examination cannot be decided on the basis that such adverse events might be detected in an early, asymptomatic stage. These events often develop rapidly so such logic is ill-founded. However, in addition to facilitating a clinical overview of the state of the anterior eye of a contact lens wearer, aftercare visits allow for a careful review of wearer compliance and an opportunity for a discussion about the availability of new products which might be more suitable for the wearer.

Assessing compliance
Certainly, the aftercare visit provides eye care practitioners with the opportunity of assessing procedures adopted by lens wearers in respect of lens wear and care, correcting any problematic issues, and reinforcing good practice.\textsuperscript{1}

Numerous studies have found that the majority of contact lens wearers are non-compliant with at least some aspects of contact lens use. For example, we conducted an extensive web-based survey of 4,021 contact lens wearers.\textsuperscript{35} Particular attention was paid to eight modifiable compliance-related behaviours which are associated with an increased risk of microbial keratitis. Full compliance was found to be rare for most lens users, although better (15\% of wearers) for those wearing daily disposable lenses – an observation that is consistent with the lower rate of corneal infiltrative events observed in those using daily disposable lenses compared with those using reusable lenses.\textsuperscript{26}

**Simplicity of daily disposable versus reusable lens wear**

The most likely reason for higher levels of compliance among wearers of daily disposable contact lenses is the simplicity of this modality of wear. Those wearing reusable contact lenses must cope with an additional layer of complexity relating to the proper use of lens care solutions and lens cases. Young\textsuperscript{36} provided a poignant illustration of the complexity of reusable lens wear and care regimens by documenting 49 steps involved in a fully compliant daily care routine when wearing reusable lenses maintained using a multipurpose lens care solution. Young\textsuperscript{36} noted that each step is critical and could pose a unique risk when missed or done incorrectly.

We have reassessed the compliance steps published by Young and have devised what we believe to be a more comprehensive list of 53 steps required for fully compliant daily lens
wear and care (Table 2). All 53 steps are relevant to reusable lens wear; however, only the 26 steps highlighted in bold in Table 2 are required for fully compliant daily disposable lens wear. It can be inferred from this analysis that daily disposable lens wearers need to be compliant with less than half the number of steps as reusable lens wearers. An important caveat to this conclusion is that it is based on the assumption that all 53 steps are equally important, which may not necessarily be the case.

Compliance behaviours associated with contact lens induced infections

We have previously identified eight modifiable compliance-related behaviours which have been shown to be related to an increase in contact lens associated infections for daily disposable, daily wear reusable, and extended wear lens use. These are listed in Table 3. Four of these behaviours relate to the use of care regimens and the lens case, three to lens wear and one to hand-washing.

Case cleaning is important in view of the 4X increase in microbial keratitis when this step is not conducted by contact lens wearers. Dantam and colleagues found that more than 80% of storage cases were contaminated when used in conjunction with four contact care solutions, irrespective of the lens material worn. Regular rinsing of the lens case using a multipurpose solution followed by tissue wiping and air-drying has been demonstrated to be effective for the removal of robust microbial biofilms. Rubbing and rinsing of contact lenses can reduce the bacterial load on a contact lens surface by 99.9%, a process which enhances overall lens disinfection. Handwashing using either ‘normal’ liquid soap and antimicrobial liquid soap can be effective in removing micro-organisms from the hands after a number of weeks of use of such products.
Enhancing compliance

Strategies that can be employed during aftercare visits to rectify the various modifiable compliance-related behaviours discussed above are not immediately obvious. Robust clinical trials conducted over the past two decades, adopting a variety of proposed compliance-enhancing strategies, have repeatedly failed to significantly improve overall compliance among lens wearers. Claydon and co-workers\textsuperscript{42} found that the repeated provision of lens care information in a variety of forms did not improve overall compliance over a 12 month observation period. A self-review strategy employed by Yung and colleagues\textsuperscript{43} failed to improve a number of behaviours. Ariwaka and colleagues\textsuperscript{44} were unsuccessful in the use of a contact lens subscriber replacement program to enhance lens care behaviour.

Despite the lack of overall success in enhancing overall compliance, two of these studies\textsuperscript{42,43} reported specific exceptions to this trend. These included measurable improvements for handwashing, case cleaning and lens rinsing – three of the four most poorly performed behaviours which we identified (Table 3) – among lens wearers who were reviewed regularly (every three months). Furthermore, training in handwashing has been shown to improve technique.\textsuperscript{45}

\textbf{The role of product advice in maintaining ocular health}

In addition to enhancing compliance, the aftercare visit provides the optometrist with an opportunity to advise the lens wearer of new contact lens options that may have become available since the last review. New products entering the market fall into two categories – major paradigm shifts, and incremental changes to product lines.

Major paradigm shifts
There have been a number of major paradigm shifts since soft lenses first became available in
the early 1970s. These include the introduction of multipurpose solutions in 1986, reusable
disposable lenses in 1988, daily disposable lenses in 1994, silicone hydrogel materials in
1998 and myopia control lenses in 2010. Most of these developments have had a positive
and profound impact on contact lens prescribing. However, as can be seen from the above
examples, such developments are infrequent, they do not all apply to all lens wearers and it is
not possible to predict when such innovations will appear.

Incremental changes

Existing product lines frequently undergo incremental changes, for example, by way of new
lens designs becoming available that are manufactured from a given lens material (e.g.
spherical, followed by toric then multifocal designs), expanded parameter ranges (e.g. lens
powers, cylinder axes, base curves, diameters), and new lens replacement frequency options.
Developments in the market since the introduction of silicone hydrogel lenses in 1998
provides a perfect example these incremental changes, by way of the gradual broadening of
the range of lens designs, introduction of new formulations of silicone hydrogel materials,
ongoing expansion of the range of available parameter, and the eventual introduction of daily
disposability.

Recommendations for aftercare visit frequency based on ocular health
considerations

Given our ranking of soft lenses into three categories in terms of the likelihood of an adverse
event and the opportunity to minimize this outcome by enhancing modifiable compliance-
related behaviours and/or reviewing the possibility of more suitable products becoming
available for patients, it is prudent to categorize the frequency of aftercare visits accordingly.
Daily disposable wearers are at low end of the risk spectrum and we therefore advocate an aftercare visit frequency of two years. Wearers of reusable soft lenses should be seen more frequently (at the long-established ‘referent’ frequency of every 12 months) where particular attention should be paid to handwashing, case cleaning and lens rinsing. Patients sleeping in soft lenses are at the high end of the risk spectrum and therefore more frequent reviews of lens management, compliance and product options are indicated; we suggest a six-monthly review schedule.

On balance, we recommend that rigid lens wearers be reviewed annually. However, if the lens wearer routinely sleeps in rigid lenses (for extended wear or orthokeratology), then aftercare visits should be conducted every 6 months.

**Maintaining good vision**

The primary reason for fitting contact lenses is to improve vision, which, in a healthy eye, should be at least 6/5. Other reasons for fitting contact lenses, which will not be discussed in detail in this review, include cosmetic enhancement with coloured lenses, myopia control, orthokeratology, and prosthetic and therapeutic applications. The various causes of vision change with contact lenses, and the way that these may impact considerations of appropriate aftercare frequencies, will be considered below.

**Correcting progressive ametropia**

The frequency of aftercare visits should be commensurate with the anticipated rate of refractive change in identified groups of lens wearers, to enable the contact lens prescription to be changed so as to preserve good visual acuity. However, it is not possible to predict future refractive changes with a high degree of accuracy.
Rate of myopia progression

Population studies have shown that the onset of myopia generally occurs around the age of 5 or 6, progresses rapidly until the mid-teens, and stabilises thereafter. Sankaridurg and Holden developed a model of myopia progression for children aged 7 to 15 years (Figure 8). These data indicate that younger children have a higher mean rate of progression compared with older children, ranging from approximately 1.00D/year at age 7 to 0.25D/year at age 15. Kinoshita and colleagues observed lower rates of myopia progression among soft contact lens wearers, ranging from 0.31D/year for eight to 13 year olds to -0.10 D/year for 20 to 22 year olds.

Stability of hyperopia

Unlike myopia, the rate of change of hyperopia at any age appears to be low. Mantyjarvi reported that any hyperopia present at age 5 or 6 generally remains constant thereafter.

Recommendation

From the standpoint of refractive change, it would seem prudent to conduct aftercare examinations every six months on myopes aged 5 to 15, given the likelihood of a clinically significant myopic shift and commensurate deterioration of vision over a six month period in this age group. Less frequent aftercare is indicated for young hyperopes or older myopes.

Correcting progressive presbyopia

The pattern of onset and progression of presbyopia is well known to optometrists. Amplitude of accommodation gradually decreases throughout life (Figure 9), which becomes problematic when there is insufficient accommodative capacity left for comfortable near
vision (presbyopia).\textsuperscript{51,52} Presbyopia typically progresses during the fourth and fifth decades of life.

There are fundamentally two ways of fully correcting presbyopia with soft contact lenses – multifocal lenses and monovision.\textsuperscript{53}

**Multifocal lenses**

Soft multifocal contact lenses, which are manufactured in a variety of designs, simultaneously correct both distance and near vision. These lenses have gained increased acceptance since the turn of the century, which is probably attributed to significant improvements in available materials, designs and modality of wear.\textsuperscript{54} Figure 10 shown the proportion of monovision and multifocal soft lens fits to those over 45 years of age in 34 countries surveyed by us in 2016.\textsuperscript{16} Clearly, multifocal contact lenses now constitute a significant proportion of all soft contact lenses prescribed to presbyopes. Rigid contact lenses can also be fitted to correct presbyopia in either simultaneous vision or alternating designs.\textsuperscript{53}

Of particular relevance to this discussion is the availability in recent times of an expanding range of near addition powers in soft multifocal lenses. Around the turn of the century, the near optical portion of multifocal contact lenses was typically available in only one near addition power.\textsuperscript{55} Today, individual brands of multifocal lenses are available in a number of near addition powers;\textsuperscript{56} for example, the Biofinity Multifocal contact lens (CooperVision, Victor, New York, USA) is available in four powers (+1.00D, +1.50D, +2.00D and +2.50D) and many other brands are available in 3 addition powers. The availability of a range of near addition powers in modern soft multifocal contact lenses allows practitioners fitting such lenses to make incremental changes to the near prescription as presbyopia advances.
Monovision

Monovision correction involves the use of single vision lenses to correct one eye for distance vision (usually the dominant eye) and the other eye for near vision. Using this approach, incremental changes of as little as 0.25D can be prescribed as presbyopia progresses. This was the most popular mode of contact lens correction for presbyopia until the turn of the century.

Recommendation

Given the progressive nature of presbyopia during the fourth and fifth decades of life, the availability of contact lenses in multiple near addition powers provides a rationale for periodic reviews of presbyopic lens wearers. To preserve comfortable near vision, aftercare visits every 12 months may be indicated during the period of advancing presbyopia.

Vision reduction due to contact lens-induced ocular pathology

In 21st century contact lens practice, four ocular complications can result in loss of vision (Figure 11). Lens-induced microbial keratitis is essentially the only complication capable of causing irreversible vision loss. Severe corneal neovascularization can impede vision if vessels encroach upon the pupillary zone, but this complication is extremely rare today. Corneal wrinkling can cause severe, short-term vision loss, but this condition is caused by poorly designed custom-made lenses, which are rarely fitted today; such cases are therefore generally unheard of in modern contact lens practice. High levels of corneal oedema can be induced by low oxygen transmissibility rigid or soft lenses and cause a transient loss of vision, but the modern-day emphasis on fitting lenses of high oxygen transmissibility largely obviates this complication. Most other ocular complications of contact lens wear are self-
limiting after cessation of lens wear and either do not affect vision or cause mild, short-term, self-limiting visual perturbances.\textsuperscript{17}

Keratitis may be thought of as a continuous spectrum of disease, ranging in severity from innocuous asymptomatic corneal infiltrates to severe and painful microbial keratitis,\textsuperscript{57} with those events occurring towards the more severe end of the spectrum typically representing a medical emergency.

Contact lens-induced keratitis

As discussed previously, severe microbial keratitis is a rare event, with an annualized incidence of 1.9 per 10,000 daily wear soft contact lens wearers and 19.5 cases per 10,000 soft extended lens wearers.\textsuperscript{24} Efron and Morgan\textsuperscript{57} analysed vision loss experienced by participants in the Manchester Keratitis Study – a 12-month, prospective, hospital-based epidemiological study of contact lens wearers suffering from corneal infiltrative events of all levels of severity. Estimates of visual acuity pre- and post-hospital attendance were obtained from the eye-care practitioners of 38 of the 118 lens wearers suffering from a corneal infiltrative event during the course of the study. As can be seen from Figure 12, approximately six months after the event, 5% and 13% of lens wearers had lost a half-line or one-line of Snellen acuity, respectively.

Conclusion

A routine aftercare visit cannot be considered as a vehicle for detecting and managing severe microbial keratitis so as to avoid loss of vision. Although lens wearers who develop painful microbial keratitis often initially present to an optometric practice for an unscheduled visit,\textsuperscript{61} the likelihood of a person with severe microbial keratitis, or even a low grade corneal
infiltrative event, presenting coincidentally to an optometric practice for a routine aftercare visit is extremely low. Accordingly, the avoidance of vision loss resulting from such conditions cannot be considered to be a reason for undertaking a routine contact lens aftercare examination.

**Vision reduction due to contact lens deposits**

Prior to the introduction of disposable contact lenses in the 1980s, it was common practice for soft contact lenses to be used for as long as they remained intact, only to be replaced when they were too uncomfortable to wear, became damaged in some way, or developed a heavy coating of deposits.\(^{20}\)

Non-regular replacement soft lenses

In a study conducted prior to the widespread use of disposable lenses, Gellatley and colleagues\(^{62}\) measured the level of deposition on soft contact lenses and the resultant loss of vision, in relation to lens age. They demonstrated that older lenses accumulated more deposits and were associated with a measurable loss of vision loss (Figure 13). This study provided an evidence-based rationale for the use of disposable contact lenses as a means of preserving vision.

Regular replacement soft lenses

**With a few notable exceptions, all soft contact lenses** prescribed at the present time are scheduled to be replaced daily, two-weekly or monthly.\(^{16}\) Accordingly, the forms of heavy deposits that can interfere with vision, which take many months or years to accumulate, are not seen in contact lens practice today. Certain endogenous entities such as proteins\(^{25}\) and
lipids can deposit on the surface of soft lenses, or be absorbed into the lens matrix, within minutes of commencing lens wear. Although such deposits may have positive or negative implications in terms of biocompatibility, there is no evidence that build-up of any form of deposits over periods of up to one month can interfere with visual performance. Therefore, preservation of vision resulting from deposit formation cannot be considered to be a rationale for routine aftercare visits for soft lens wearers.

Rigid lenses

Woods and Efron observed significant mucous coating on the surface of rigid lenses that were not regularly replaced. It has been suggested that excess mucus is implicated in adhesion of rigid lenses to the cornea when worn overnight. Therefore, to monitor for excess lens deposition, rigid lens wearers who sleep in lenses (for extended wear or orthokeratology) may need to be reviewed every six months.

Optimizing comfort

Discomfort during contact lens wear, especially towards the end of the day (so-called 'end of day discomfort'), is a general source of displeasure among contact lens wearers. Ensuring that soft contact lenses are comfortable throughout the waking hours is perhaps the greatest challenge in the contact lens field today.

Prevalence of soft contact lens discomfort

Brennan and Efron documented high levels of discomfort experienced with early-generation hydrogel lenses manufactured from hydroxyethyl methacrylate; specifically, they noted that 75 per cent of 104 lens wearers surveyed experienced symptoms of discomfort (reported as dryness) on at least some occasions.
Little has changed in the ensuing quarter of a century. Dumbleton and colleagues\textsuperscript{69} reviewed all reports of population-based studies documenting contact lens discomfort published between 1986 and 2011 and noted that, in those who continue to wear contact lenses, the prevalence of contact lens discomfort and dryness symptoms reported in the literature has been remarkably consistent, with rates averaging around 50%. They noted that this is significantly greater than the rates that have been reported in non-lens wearers.

Dumbleton and colleagues\textsuperscript{69} also reviewed all reports of clinical practice/hospital-based studies of contact lens discomfort published between 1997 and 2012 and found the reported prevalence of contact lens discomfort and dryness symptoms to range from 28 to 50%.

**Causes of soft lens-induced discomfort**

The Tear Film and Ocular Surface Society International Workshop on Contact Lens Discomfort, involving 80 contact lens experts, addressed the issue of contact lens discomfort and published their findings in a special issue of the prominent journal Investigative Ophthalmology and Visual Science (Volume 54, No. 11, October 2013) which was devoted exclusively to this topic.\textsuperscript{70} Numerous factors were identified as having an impact on lens comfort, which were broadly classified into ‘contact lens’ or ‘environmental’\textsuperscript{70} (Figure 14).

**Lens changes versus eye fatigue**

Papas and colleagues\textsuperscript{71} recently conducted an experiment to establish whether end-of-day discomfort during soft contact lens wear is associated with short-term changes occurring to the lens itself or to the eye. Study participants wore hydrogel and silicone hydrogel lenses for 10 hours on multiple occasions. On some occasions, the lenses were worn continuously for
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10 hours; during these experiments, a continual decline in comfort was observed with wear of both hydrogel and silicone hydrogel lenses. On other occasions, at the 5 hour mid-point, lenses were removed and either replaced with the same lens after being rinsed, or replaced with a new lens.

It was observed that for both lens types, comfort progressively decreased throughout the day to the same extent in all wearing/interruption scenarios, except for a slight transient increase in comfort at the 5 hour lens removal mid-point. Papas and colleagues concluded that end-of-day comfort was probably due to fatigue in one or more ocular tissues, or stimulation of ocular surface nociceptors induced by the presence of the contact lens.

Sub-clinical inflammation

More recently, it has been proposed that discomfort may arise as a result of the intrinsically sub-clinical inflammatory response of the eye to contact lens wear. Preliminary studies have demonstrated a link between the mobilisation of inflammatory cells and contact lens-induced discomfort. The association between lens-induced discomfort and the upregulation of inflammatory mediators in ocular tissues during lens wear is less clear.

Strategies for alleviating soft lens-induced discomfort

The Tear Film and Ocular Surface Society International Workshop on Contact Lens Discomfort identified a number of strategies for alleviating contact lens discomfort, and provided an elegant strategic pathway for investigating and managing this (see below). However, the workshop failed to offer a clear solution for end-of-day discomfort.
Until the causes and cures of end-of-day discomfort with soft lenses are determined, practitioners can only resort to decision pathways defined by current knowledge to resolve such issues in individual lens wearers, such as that advocated by the Tear Film and Ocular Surface Society International Workshop on Contact Lens Discomfort (Figure 15).\(^1\) Although discomfort issues often need to be addressed at routine aftercare visits, there is no clear rationale for a specified frequency of visits to ensure lens comfort.

**Rigid lens discomfort**

Rigid corneal contact lenses are initially uncomfortable due to physical interactions between the sensitive eyelid margins and the lens edge.\(^2\) The majority of those fitted with rigid lenses are able to adapt to this discomfort, although some are unable to adapt and discontinue from lens wear. Rigid semi-scleral lenses appear to be well tolerated,\(^3\) with a reported drop-out rate of 13% when such lenses were fitted to manage cases of irregular cornea.\(^4\)

**Ensuring satisfactory lens fitting performance**

A good fitting contact lens is essential for providing good comfort, clear and stable vision, and the avoidance of microtrauma to the ocular tissues. Accordingly, assessing the lens fitting performance of a contact lens is an essential component of the aftercare examination.

**Soft lenses**

Optometrists are well versed in the requirements for a satisfactory soft lens fit: the lens must sit centrally on the cornea with a 1-2 mm overlap onto the limbus; there should be no lens edge compression (sign of a tight fit) or lens edge lift (sign of a loose fit); the lens should move about 0.25mm with each blink; a slight lag on lateral gaze or upgaze is acceptable as long as the limbus is not exposed, etc.\(^5\) New technologies for assessing how a soft lens fits
to the cornea are becoming available, such as ultra-high resolution anterior eye optical coherence tomography (Figure 16). Additional assessments are required for toric lenses (e.g. to assess cylinder axis alignment and stability) and multifocal lenses. As well, the lens surface, examined under the slit lamp biomicroscope, should be covered with an even tear film that is maintained for at least 10 s following a blink. Attempts can be made to remedy any deficits in lens performance by changing the lens material, parameters or design as required.

Rigid lenses
The performance of rigid lenses is assessed by inspecting how the lens positions on the cornea, moves with blinking and locates in relation to the eyelids. The physical relationship between the anterior corneal and posterior lens surfaces or the lens edge can be determined using fluorescein (Figure 17). As with soft lenses, deficits in any of these performance indicators can usually be resolved by fitting another lens with different parameters.

Conclusions
Dimensions of the anterior eye generally remain stable throughout life; the small changes that are known to occur are of insufficient magnitude to significantly alter the performance of soft and rigid lenses over a period of many years once an initial satisfactory fit has been established. Perhaps the only circumstance that can alter lens fit significantly is the development of ocular pathologies which alter the physical characteristics of the anterior eye. For example, soft lenses tend to exhibit greater movement with blinking in the presence of papillary conjunctivities or dry eye and a pterygium or pinguecula may affect the movement of a rigid lens. Accordingly, in respect of lens performance, the suggested
aftercare frequency should be aligned to that recommended in relation to ocular health considerations, as discussed above.

**DROP-OUTS FROM LENS WEAR AND THE IMPORTANCE OF EARLY REVIEW OF NEOPHYES**

The aftercare visit offers an opportunity for taking action that will minimise the propensity for discontinuation from lens wear. Contact lens discontinuation, or ‘drop out’, is arguably the greatest problem facing contact lens practice, costing practitioners and the contact lens industry hundreds of millions of dollars each year. Optometry practices suffer through lost income\(^{86}\) and possibly a loss of customer loyalty through dissatisfaction. Lens wearers who drop out due to discomfort are often frustrated by the inability to wear lenses throughout each day in the period leading up to cessation of lens wear, as well as the ultimate inability to be able to improve vision using their desired form of optical correction if lens wear is discontinued.

**Drop-out rate**

A review of eight contact lens discontinuation studies conducted between 1993 and 2013 by Sulley and coworkers\(^{87}\) found a high rate or temporary or permanent discontinuation, ranging from 12 to 51 per cent. Despite significant advances in contact lens designs, materials and modalities of wear over the past two decades, the rate of contact lens discontinuation has remained disappointingly high.

The findings of two major surveys of contact lens drop out, conducted 14 years apart, reveal a similar rate of contact lens discontinuation, despite being conducted at different phases of the history of contact lens development (Figure 18). In 1999, Pritchard and colleagues\(^{88}\)
analysed 1,444 survey forms gathered from lens wearers in 16 clinical practices in Quebec, Canada, and found that 34 per cent had discontinued lens wear at least once. At the time of this study, virtually all soft lens wearers surveyed would have been wearing conventional hydrogel contact lenses.

A similar study conducted by Dumbleton and colleagues in 2013 assessed 4,207 returned survey forms distributed via Facebook and reported that 40 per cent of those surveyed had lapsed from lens wear for at least four months. At the time of this study, silicone hydrogel contact lenses had been on the market for over a decade; 45 per cent of those surveyed by Dumbleton and colleagues were wearing this lens type, and 38 percent of these silicone hydrogel lens wearers had dropped out. It is interesting that the development of high oxygen transmissibility silicone hydrogel contact lenses with supposedly superior biocompatibility, at least in terms of the amelioration of hypoxic problems, did not appreciably diminish the rate of contact lens discontinuation.

**Reasons for drop-out**

The reasons cited for discontinuation were remarkably consistent across studies the eight studies surveyed by Sulley and coworkers, with the most frequent reason being discomfort (range across studies 41 to 64 per cent), followed by vision problems (0 to 18 per cent) and handling difficulties (0 to 7 per cent). The impact that problems with discomfort and vision have in relation to the frequency of contact lens aftercare visits has been discussed previously in this review.

Ewbank reported the findings of a survey conducted in the United Kingdom which indicated that the three main reason for dropping out of contact lens wear were that the lenses
were too expensive (22 per cent), health problems with lenses (22 per cent) and discomfort (21 per cent). This study highlights the importance of price sensitivity for many lens wearers.

Neophyte drop outs

Sulley and coworkers\textsuperscript{87} conducted a retrospective chart review of the records for 524 neophyte contact lens wearers (i.e. those wearing lenses for the first time) fitted at 29 representative eye care practices in the United Kingdom. After 12 months, 388 were still wearing lenses, indicating an annualized dropout rate of 26 per cent. Of the 136 lapsed wearers, 25 per cent discontinued during the first month and 47 per cent within two months. The main reasons cited for discontinuation included poor distance vision (26 per cent), poor near vision (16 per cent), discomfort (14 per cent) and handling problems (15 per cent).

These findings highlight the importance of reviewing neophyte lens wearers within the first two months after fitting, and to enquire into (and resolve if possible) any difficulties being encountered, which may relate to dissatisfaction with vision, comfort or lens handling. Issues of cost can be discussed with the lens wearer, assisted by a cost-per-wear model, which helps illustrate the real difference in cost between difference lens replacement modalities in the context of the frequency of lens wear.\textsuperscript{91}

SUGGESTED FREQUENCY OF AFTERCARE VISITS

Table 4 provides a matrix for considering the appropriate frequency of aftercare visits that apply various categories of lens wearers, based on the conclusions reached in relation to the clinical reasons for conducting aftercare visits, as discussed above. There are two mutually exclusive domains that guide this decision making, which are based on: (1) lens replacement frequency, wearing modality (daily or extended wear) and type (soft or rigid); and (2) the
predicted rate of refractive change. If a lens wearer meets two criteria with different aftercare frequencies, the higher frequency should be adopted.

Caveats

It is important to stress that these are general guidelines, and that decisions about an appropriate aftercare frequency must be tailored to the circumstances of individual lens wearers. In this regard, it is necessary to consider numerous caveats that require deviation from the recommended aftercare visit frequencies summarized in Table 4. The following is by no means a complete list, but serves to illustrate the flexible approach required in making such determinations:

- Orthokeratology involves the wearing of rigid lenses overnight\textsuperscript{92} to physically reshape the cornea so as to provide corrected vision while the therapy continues. Frequent modifications in lens design may be required, and the physical and physiological integrity of the cornea needs to be closely monitored. Accordingly, frequent aftercare visits are required at various phases of the treatment, whether it is used to correct stable myopia or for to arrest the progression of myopia (‘myopia control’).

- Myopes fitted with lenses designed for myopia control may need to be examined more frequently to monitor the efficacy of the treatment.\textsuperscript{93}

- Paediatric lens fitting may require more frequent aftercare visits as refraction is changing more rapidly and young children are likely to be fitted with contact lenses due to greater refractive or clinical need.\textsuperscript{94} Some studies have indicated that children have a greater propensity for adverse events,\textsuperscript{95,96} although other have found low rates of contact lens-associated ocular complications in children.\textsuperscript{94}

- Therapeutic applications such as paediatric aphakia require frequent aftercare visits given the complexity of fitting contact lenses to infants and the fact that there is rapid growth of
the eye during the first 18 months of life. Lindsay and Chi\textsuperscript{97} recommend after-care visits every four to six weeks once contact lenses have been fitted successfully. If the infant is wearing the contact lenses on an extended wear basis, more frequent review may be required.\textsuperscript{97}

- High ametropia may require frequent aftercare visits, especially if refraction is changing rapidly. High ametropia (> 5.00D) also carries an increased risk of 1.5X for any adverse event and 1.9X for other infectious events compared with low ametropia.\textsuperscript{98} As well, high myopia carries a higher risk of associated ocular complications, such as posterior subcapsular, cortical and nuclear cataract; glaucoma; chorioretinal abnormalities such as retinal detachment, chorioretinal atrophy and lacquer cracks; and tilted, rotated, and larger discs as well as other optic disc abnormalities.\textsuperscript{99}

- Lens wearers with corneal pathology such as keratoconus, corneal dystrophy or postkeratoplasty generally require more frequent aftercare visits as part of their management compared with uncomplicated cosmetic lens wearers. Downie and Lindsay\textsuperscript{100} emphasize the importance of monitoring for disease progression in patients with keratoconus, in particular children, who tend to undergo more rapid changes, so as to facilitate appropriate modification to contact lens fitting.

- Lens wearers fitted post-refractive surgery may need to be seen more frequently during the first 12 months following surgery, as corneal sensitivity may be reduced and there is a greater propensity for dry eye.\textsuperscript{101}

- Lens wearers deemed or predicted to be poorly compliant with lens care regimens, or who have a history of non-compliance, may need to be seen more frequently in view of the link between non-compliant behaviours and adverse ocular reactions.\textsuperscript{35}
A higher risk taking personality style of contact lens wearers is associated with less compliant lens care behaviour. Therefore, lens wearers deemed to have a higher risk taking personality may require more frequent aftercare visits.

Wearers of reusable lenses who are outside the range of rapidly advancing myopia or presbyopia, and deemed to be responsible, risk-averse and fully compliant with lens care regimens, perhaps only need to be seen every two years in view of the link between compliant behaviours and ocular health.

Lens wearers displaying evidence of lens-induced pathology, or who are recovering from an adverse event, may need to be monitored more frequently, especially during the active or recovery phase of the condition.

Neophyte wearers should be examined within the first two months of being fitted with lenses in view of the high risk of discontinuation from lens wear in this demographic category.

Scheduling aftercare visits

The potential for detecting problems that need to be addressed at a contact lens aftercare visit can be maximised by suggesting that the lens wearer synchronise lens usage leading up to the aftercare visit so that at the time of presentation to the practice, the lenses being worn are at the end of the replacement cycle. For example, a lens wearer using monthly replacement daily wear lenses should present with lenses that have been worn on a daily basis for one month.

As well, the examination of daily lens wearers is best conducted after at least four hours of lens wear on the day of the aftercare visit. Where there is overnight use of lenses, an early morning appointment is favoured to potentially detect issues arising from closed eye lens
wear. Under such conditions, any problems with the integrity of the lens or ocular tissues, or deficits in vision or comfort, are more likely to manifest and can be addressed accordingly.

COMMERCIAL CONSIDERATIONS

While the aftercare examination is primarily a clinical concern, commercial factors also come into play in relation to the professional time associated with this activity and the provision of contact lenses. Accordingly, a comprehensive overview of contact lens aftercare must give due consideration to potential commercial influences.

Professional consultation fees

Optometrists are highly trained health care professionals, and as is the practice and custom for all health care workers, are entitled to derive fair remuneration for time spent consulting with lens wearers. This principle ought to apply to both scheduled and unscheduled contact lens aftercare examinations.

Subsidised contact lens care

In some countries, such as Australia, contact lens consultation fees are reimbursed wholly or partially under national health care schemes only if certain stringent conditions are met, such as high levels of refractive error being corrected. Consideration of remuneration for professional time in the context of different national health care schemes, in relation to contact lens consultations, is beyond the scope of this review. Therefore, for the sake of discussion, it will be assumed that the lens wearer is paying the full fee.

Annual consultation fee
The level of profitability resulting from aftercare visits will depend upon the relation between the fee structure and the aftercare frequency that is adopted. One approach is to levy an ‘all-inclusive’ annual fee for aftercare visits, which entitles the lens wearer to consult with the optometrist as many times as deemed necessary during the prescribed 12 month period. Under such an arrangement, practice profitability will be inversely related to the number of times the lens wearer comes to the practice for a consultation and the length of the visits, based on the assumption of an association between ‘chair time’ and practice income.

**Fee for service**

An alternative approach is to adopt a ‘fee for service’ arrangement, whereby the lens wearer pays for each service rendered. Under this arrangement, practice profitability will be directly related to the number of times the lens wearer comes to the practice for a consultation and the length of the visits, based on the same assumption as above of an association between ‘chair time’ and practice income.

Whichever of these approaches is adopted, a primary consideration should be the needs of the lens wearer, taking into account factors such as convenience, affordability, and the likelihood of delivering the best possible clinical care so that lens wear affords good vision and is safe and comfortable. That is, the income derived from aftercare examinations should be an important consequence, rather than a driver, of the fee structure adopted.

**Contact lens product sales**
In most countries, lens wearers have the option of purchasing their lens and solution supply from the practice, or through non-optical-practice supply routes such as commercial retail outlets (supermarkets, convenience stores, beauty parlours, beauty salons, video stores, flea markets, tattoo parlours, delicatessens, etc.), \(^{103}\) telephone ordering, the internet and vending machines (Figure 19). Virtually all contact lens types can be purchased through such unregulated supply routes.

**Potential dangers of internet purchase**

Contact lenses are particularly susceptible to third-party distribution given the brand awareness that many of these products have with the public.

**United Kingdom**

A survey conducted in the United Kingdom in 2013 found that 10 per cent of lens wearers usually purchased their lenses over the internet.\(^ {15}\) A further 17 per cent who did not usually buy online had done so in the past, and 26 per cent had either considered or researched the possibility of internet purchase. It was also found that 14 per cent of those who use daily disposables buy their lenses online, compared to only 7 per cent of re-usable lens wearers.

**United States**

A survey of eye care practitioners (of which 80 percent were optometrists) conducted in the United States in 2016 found that 67 percent of lens wearers purchased contact lenses from their practice, whereas 18 per cent purchased lenses online, 13 percent purchased lenses through a third-party retailer independent of a practice, and 2% purchased lenses from another practice setting.\(^ {104}\)
Another potential danger associated with internet purchase is product substitution. An online vendor who does not stock the specific brand or parameters of a lens prescribed by an optometrist might provide an alternative product that is unsuitable for the lens wearers. For example, a lens wearer seeking to purchase a silicone hydrogel might be supplied with a conventional hydrogel lens, erroneously deemed by the vendor to be an ‘equivalent product’. In this regard, the USA Food and Drug Administration advises lens wearers: “Beware of attempts to substitute a different brand than you presently have. While this may be acceptable in some situations, there are differences in the water content and shape between different brands. The correct choice of which lens is right for you should be based only on an examination by your eye care professional, not over the phone.”

Clinical impact of internet lens purchase

There is divided opinion on the clinical impact of the choice that lens wearers make in respect of the source of their contact lens supply. Fogel and Zidile\textsuperscript{106} suggested that contact lenses purchased over the internet placed individuals potentially at risk for harmful eye care practices. Stapleton and colleagues\textsuperscript{24} reported that internet purchase of contact lenses carried a 5X greater risk factor for developing microbial keratitis compared with purchase from an eye care practitioner. Sorbara and colleagues\textsuperscript{107} observed that lens wearers with serious and significant contact lens-related corneal inflammatory events were more likely to purchase soft contact lenses on the internet versus those who did not suffer from such events.

Wu and co-workers\textsuperscript{108} found that lens wearers who purchased contact lenses from the internet were 3.8 times more likely to forget their aftercare schedule than those who purchased contact lenses from optometrists.
In contrast to some of the concerns outlined above, Chalmers and colleagues\textsuperscript{109} found no difference in soft contact lens habits or differences in the prevalence of risk behaviours between lens wearers who bought lenses from their eye care practitioner, on the internet/telephone, or at retail stores other than where they were examined.

Young and colleagues\textsuperscript{103} reviewed 23 articles, representing 70 individual cases, concerning complications associated with contact lenses obtained from unregulated sources of supply. They concluded that there are various reasons to suggest that the unregulated supply of contact lenses might result in the use of inappropriate lenses, increase the risk of poorer lens and lens case hygiene, and militate against the prompt treatment of any consequent problems.

It follows from the observations of Young and colleagues\textsuperscript{103} that it is in the public interest to arrange lens supply in such a way that ongoing preservation of the ocular health of lens wearers is guaranteed. Young and colleagues\textsuperscript{103} concluded that a system that provides no disincentives for lens wearers to continue to purchase lenses for many years without having their eyes examined poses a significant public health risk.

**Strategies to counteract internet purchase**

Notwithstanding the role of regulatory authorities in discharging their responsibilities for public health and safety, there are strategies that practitioners can employ – in the interest of the ocular well-being lens wearers – to retain control of lens supply and to link this to contact lens care.

**Fee splitting**
Fee splitting – where materials are charged at relatively low mark-ups on cost and these charges are separated from professional fees – helps demonstrate to lens wearers that most of the cost involved in wearing contact lenses is attributed to the professional time involved. A survey conducted in the United Kingdom found that 83 per cent of contact lens wearers were likely to purchase lenses from their optometrist if they were charged a consulting fee and the cost of lenses matched internet prices.90

**Practice-controlled home delivery**

Home delivery plans, perhaps operated on behalf of the practice by a supplier, enable practitioners to match the perceived convenience of mail order and internet supply companies. Large practices or practice groups may be able to come to an arrangement with manufacturers so that lenses and solutions supplied by that manufacturer are ‘rebranded’ prior to delivery. The rebranding (or so-called ‘own-labelling’ or ‘private labelling’) facilitates an association of the products with the practice and thereby serves to enhance customer loyalty. However, as the lens specifications cannot be altered, it is relatively straightforward to determine the original brand and purchase the original brand elsewhere if desired.

**Strategic lens supply**

A strategy that may be used in some instances to encourage compliance with attendance for aftercare visits is to match lens supply with the intended aftercare visit frequency. For example, a lens wearer who is advised to present for six-monthly aftercare visits could be provided with a six month supply of lenses, therefore providing an incentive to return after six months for an aftercare examination and a resupply of lenses.
Supplementary sales

Virtually all contact lens wearers are also spectacle wearers. Thus, an aftercare examination provides an opportunity to remind the lens wearer if a general eye examination is due or to offer assistance in respect of any other eye care requirements, such as updated spectacles, sunglasses etc.

CONCLUSIONS

In this review, we have attempted to provide an overarching model of contact lens aftercare, highlighting issues that are of relevance to 21st century optometric practice. Consideration has been given to clinical reasons for conducting aftercare visits, with a view to developing guidelines in relation to appropriate aftercare frequencies for different categories of lens wearers.

Our general view is that, as a result of significant advances in contact lens technology over the past three decades, contact lens wear is more ‘user friendly’ than ever before. Practitioners have numerous options in terms of lens material, designs and replacement frequencies, such that contact lenses can be more closely aligned to the optical, physiological, lifestyle and financial requirements of individual lens wearers. Accordingly, it is deemed appropriate for there to be a relaxation, in many circumstances, of the somewhat inflexible approach of the past of advocating six to 12-monthly aftercare visits for all lens wearers.

Implications for regulatory authorities

Authorities overseeing the supply of contact lenses to the public have an obligation to align any regulations, or advice on the length of validity of a contact lens prescription, with the
clinical requirements for safe contact lens wear. It is desirable that such regulations do not conflict with the recommended frequency of aftercare visits given to lens wearers.

**Australia**

In its ‘Guidelines on the Prescription of Ocular Appliances’, the Optometry Board of Australia stipulates the following: “When nominating an expiry date for a prescription, the optometrist should choose a date beyond which he or she is not willing to state that the prescription is appropriate to the patient.”

**United Kingdom**

In the United Kingdom, the Opticians Act 1989: Part 4, Section 25(7)(a) states: “A specification … must … state the period during which the specification remains valid and its expiry date.” Further clarification and guidance for lens wearers is provided in a brochure published jointly by the General Optical Council of the United Kingdom and the British Contact Lens Association, which states: “Your contact lens practitioner will advise you how long your specification is valid, depending on things like the lens type, wearing schedule and replacement frequency, and your eye health. Your practitioner may recommend that you receive only a limited number of lenses at any one time, such as a maximum of six months’ supply or the number of lenses you are likely to need before the expiry date of your specification.”

**Advice to regulatory bodies**

The approach adopted by Australian and British lawmakers essentially allows the optometrist to set the period of validity of a contact lens prescription. Aligning this time frame with the indicated aftercare frequency for various circumstances shown in Table 4 will serve as an
incentive for lens wearers to return for aftercare examinations at the prescribed time frequency. This tailored approach to contact lens aftercare is in the best interests of lens wearers in terms of health and safety, and we would advocate that all authorities charged with the responsibility of overseeing the supply of contact lenses follow the enlightened Australian and British regulatory models.

**Future directions**

Empirical evidence is required to determine the optimal aftercare visit frequency for contact lens wearers. This could be achieved by conducting a controlled, double-masked and randomised study, in which lens wearers are randomly assigned into groups that are advised to adopt various aftercare visit frequencies. The end-point outcome measures for such a study would include vision, level of comfort, ocular health and rate of discontinuation from lens wear. Such a study would likely be very expensive and take many years to complete. An added complication is that participants would need to be stratified into lens type and refractive status, which may require thousands of participants to generate sufficient power for statistically valid results.

Until such a study is undertaken, optometrists must decide on the optimum aftercare frequency for each lens wearer, based on demographic, general health and ocular considerations; the likelihood of compliance with instructions; the type of lenses being worn; and the prescribed lens replacement frequency. The factors discussed in this review may provide a helpful framework for such deliberations.

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<td>Corneal epithelium</td>
<td>Oedema</td>
<td>Staining&lt;sup&gt;c&lt;/sup&gt;</td>
<td>Microcysts</td>
</tr>
<tr>
<td></td>
<td>Wrinkling</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Thinning</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Corneal stroma</td>
<td>Oedema</td>
<td>Warpage</td>
<td>Thinning</td>
</tr>
<tr>
<td></td>
<td>Microbial keratitis&lt;sup&gt;b&lt;/sup&gt;</td>
<td>Deep opacities</td>
<td>Vascularization&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>Infiltrates&lt;sup&gt;b&lt;/sup&gt;</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Corneal endothelium</td>
<td>Blebs</td>
<td>Polymegethism</td>
<td>Bedewing</td>
</tr>
</tbody>
</table>

Can also involve (a) tear film, (b) corneal epithelium, (c) corneal stroma, (d) limbus

* Bold font indicates hypoxic aetiology, at least in part.

Table 1. Acute and chronic ocular complications of contact lens wear
<table>
<thead>
<tr>
<th>Lens Insertion</th>
<th>Lens Removal</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Wet hands&lt;sup&gt;a&lt;/sup&gt;</td>
<td>27. Wet hands</td>
</tr>
<tr>
<td>2. Apply soap</td>
<td>28. Apply soap</td>
</tr>
<tr>
<td>3. Rub hands</td>
<td>29. Rub hands</td>
</tr>
<tr>
<td>4. Rinse hands</td>
<td>30. Rinse hands</td>
</tr>
<tr>
<td>5. Dry hands</td>
<td>31. Dry hands</td>
</tr>
<tr>
<td>6. Check eyes look healthy</td>
<td>32. Remove bottle lid</td>
</tr>
<tr>
<td>7. Remove bottle lid</td>
<td>33. Fill R case with solution</td>
</tr>
<tr>
<td>8. Open R side of case</td>
<td>34. Remove R lens</td>
</tr>
<tr>
<td>9. Remove R lens from case</td>
<td>35. Apply solution to R lens</td>
</tr>
<tr>
<td>10. Rinse R lens</td>
<td>36. Rub R lens</td>
</tr>
<tr>
<td>11. Drain R lens</td>
<td>37. Rinse R lens</td>
</tr>
<tr>
<td>12. Check R lens</td>
<td>38. Put R lens in case</td>
</tr>
<tr>
<td>14. Open L side of case</td>
<td>40. Fill L case with solution</td>
</tr>
<tr>
<td>15. Remove L lens from case</td>
<td>41. Remove L lens</td>
</tr>
<tr>
<td>16. Rinse L lens</td>
<td>42. Apply solution to L lens</td>
</tr>
<tr>
<td>17. Drain L lens</td>
<td>43. Rub L lens</td>
</tr>
<tr>
<td>18. Check L lens</td>
<td>44. Rinse L lens</td>
</tr>
<tr>
<td>19. Insert L lens</td>
<td>45. Put L lens in case</td>
</tr>
<tr>
<td>20. Check vision is good</td>
<td>46. Close L case lid</td>
</tr>
<tr>
<td>21. Check lenses are comfortable</td>
<td>47. Replace bottle lid</td>
</tr>
<tr>
<td>22. Replace lid on bottle</td>
<td>48. Soak lenses overnight</td>
</tr>
<tr>
<td>23. Empty case of solution</td>
<td>49. Replace case monthly</td>
</tr>
<tr>
<td>24. Clean case: solution rinse</td>
<td>50. <strong>Discard lenses as per schedule</strong></td>
</tr>
<tr>
<td>25. Clean case: tissue wipe</td>
<td>51. Discard solution bottle as per schedule</td>
</tr>
<tr>
<td>26. Clean case: air dry</td>
<td>52. <strong>Do not exceed advised wearing time</strong></td>
</tr>
<tr>
<td>53. Attend for regular aftercare</td>
<td></td>
</tr>
</tbody>
</table>

a. Adapted from Young.<sup>36</sup>

b. All 53 steps are relevant to reusable lenses. Only the 26 steps highlighted in **bold** are relevant to daily disposable lenses.

Table 2. The 53 steps for fully compliant daily lens wear and care<sup>a</sup>
<table>
<thead>
<tr>
<th>Behaviour</th>
<th>Lens Type</th>
<th>Relative Risk/Odds Ratio*</th>
<th>Required Steps for Compliance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inadequate hand-washing</td>
<td>DD, DW, EW</td>
<td>4.5</td>
<td>Hands washed before application and removal with soap, hand sanitizer or wet wipe.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1.5</td>
<td></td>
</tr>
<tr>
<td>Non-prescribed overnight wear</td>
<td>DD, DW</td>
<td>4.0 if worn overnight at least once per fortnight</td>
<td>No accidental or intentional overnight wear</td>
</tr>
<tr>
<td>Excessive duration of extended wear</td>
<td>EW</td>
<td>6.7 if used for six or more nights</td>
<td>No overnight use beyond that recommended by eye care practitioner.</td>
</tr>
<tr>
<td>Excessive lens replacement interval</td>
<td>DD, DW, EW</td>
<td>4.8</td>
<td>Lenses not used beyond the recommended replacement interval</td>
</tr>
<tr>
<td>Inadequate case cleaning</td>
<td>DW, EW</td>
<td>4.0</td>
<td>Case cleaned with contact lens solution each time lenses used.</td>
</tr>
<tr>
<td>Failure to use correct disinfecting solution</td>
<td>DW, EW</td>
<td>55.9 if no disinfection employed</td>
<td>Multi-purpose solution or hydrogen peroxide used on a regular basis.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>21.8 if lenses stored in tap water</td>
<td>No reporting of topping off.</td>
</tr>
<tr>
<td>Failure to rub and rinse lenses</td>
<td>DW, EW</td>
<td>3.5</td>
<td>Lens rub-cleaned and rinsed after removal, unless care regimen is specifically a ‘no-rub’ product.</td>
</tr>
<tr>
<td>Topping off solution</td>
<td>DW, EW</td>
<td>2.5</td>
<td>All solution replaced with fresh solution for each lens storage occasion. No reporting of topping off.</td>
</tr>
</tbody>
</table>

* In the case of events with very low incidence (such as contact lens infections), values for relative risk and odds ratios are numerically very similar.

Adapted from Morgan and colleagues

Table 3. Modifiable compliance-related behaviours which have been shown to be related an increase in contact lens associated infections for daily disposable (DD), daily wear reusable (DW) and extended wear (EW) lens use.
Based on lens replacement frequency, lens type and wearing modality

<table>
<thead>
<tr>
<th></th>
<th>After 1-2w</th>
<th>Every 6m</th>
<th>Every 12m</th>
<th>Every 24m</th>
<th>Rationale</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soft daily disposable</td>
<td>✔</td>
<td></td>
<td></td>
<td></td>
<td>Lower risk of keratitis</td>
</tr>
<tr>
<td>Soft daily reusable</td>
<td>✔</td>
<td>✔</td>
<td></td>
<td></td>
<td>Adverse solution reactions and compliance issues</td>
</tr>
<tr>
<td>Soft extended wear</td>
<td>✔</td>
<td>✔</td>
<td></td>
<td></td>
<td>Higher risk of keratitis</td>
</tr>
<tr>
<td>Rigid daily wear</td>
<td>✔</td>
<td></td>
<td>✔</td>
<td></td>
<td>Lower risk of keratitis, but higher risk of eyelid ptosis, 3&amp;9 o’clock staining and corneal deformation</td>
</tr>
<tr>
<td>Rigid extended wear</td>
<td>✔</td>
<td>✔</td>
<td></td>
<td></td>
<td>Higher risk of keratitis, eyelid ptosis, 3&amp;9 o’clock staining, corneal deformation and overnight lens mucus adhesion</td>
</tr>
</tbody>
</table>

Based on predicted rate of refractive change

<table>
<thead>
<tr>
<th></th>
<th>After 1-2w</th>
<th>Every 6m</th>
<th>Every 12m</th>
<th>Every 24m</th>
<th>Rationale</th>
</tr>
</thead>
<tbody>
<tr>
<td>Youth myopia (5-15y)</td>
<td>✔</td>
<td>✔</td>
<td></td>
<td></td>
<td>Myopia advances -0.50D annually</td>
</tr>
<tr>
<td>Presbyopia</td>
<td>✔</td>
<td>✔</td>
<td></td>
<td></td>
<td>Progressive accommodation loss</td>
</tr>
</tbody>
</table>

a After taking delivery of lenses for the first time, those new to lens wear (neophytes) should be seen again within the first 2 months.
b If two criteria are met suggesting different aftercare frequencies, the higher frequency should be adopted.
c It is customary for daily disposable lens wearers to be given an initial trial supply of 5 pairs of lenses. Accordingly, the ‘1-2w’ aftercare should be undertaken on the day that the fifth pair of lenses are worn, which may be after ≥ 5 days depending if lenses are worn on a part-time basis.
d Referent aftercare visit schedule.

Table 4. Decision matrix for recommending an appropriate aftercare visit schedule based on lens replacement frequency, lens type, wearing modality and predicted rate of refractive change

"a,b"
Figure legends

Figure 1 Types of deposits forming on soft lenses observed in the 1980s. (A) ‘Jelly bumps’ or ‘mulberry deposits’, which were thought to be composed of a combination of mucus, lipid, protein and calcium; (B) iron deposits; (C) protein deposits; (D) Calcium deposits. Images by Patrick Caroline courtesy of the Bausch & Lomb Slide Library.

Figure 2 Proportion of lens wearers presenting for aftercare visits at various frequencies. After Ewbank.\textsuperscript{15}

Figure 3 Ocular reactions to contact lens wear with are (A) asymptomatic, such as endothelial blebs (courtesy of Steve Zantos, Bausch & Lomb Slide Collection), and (B) symptomatic, such as papillary conjunctivitis (courtesy of Eric Papas, Bausch & Lomb Slide Collection)

Figure 4 Proportion of soft lens new fits prescribed in Australia in 2016 as a function of lens replacement frequency, showing that 99 per cent of all soft lenses are replaced at least monthly. Data from Morgan and colleagues.\textsuperscript{16}

Figure 5 Trends in the fitting of silicone hydrogel contact lenses in 14 nations between 2000 and 2016. Data from Morgan and colleagues.\textsuperscript{16}

Figure 6 Relation between material oxygen permeability (Dk) and water content for silicone hydrogel and conventional hydrogel contact lenses.

Figure 7 Trends in the fitting of daily disposable contact lenses in 14 nations between 2000 and 2016. Data from Morgan and colleagues.\textsuperscript{16}
Figure 8  Progression model for spherical equivalent refractive error for Asian children with myopia. After Sankaridurg and Holden.48

Figure 9  The decline in monocular subjective amplitude of accommodation, referenced to the spectacle plane, with age. After Charman.51

Figure 10  Proportion of monovision and multifocal lens fits to those over 45 years of age in 34 countries 2016. Country codes: AU Australia; BE Belgium; BG Bulgaria; CA Canada; CH Switzerland; CN China; CZ Czech Republic; DE Germany; DK Denmark; ES Spain; FI Finland; GR Greece; HK Hong Kong; HU Hungary; ID Indonesia; IL Israel; IR Iran; IT Italy; JP Japan; KR Korea; LT Lithuania; MD Moldova; NL Netherlands; NO Norway; NZ New Zealand; PH Philippines; PT Portugal; RU Russia; SE Sweden; SI Slovenia; TH Thailand; TW Taiwan; UK United Kingdom; US United States. After Morgan and colleagues.16

Figure 11  Contact lens complications that can result in loss of vision. (A) Microbial keratitis (courtesy of Andrew Tullo); (B) corneal neovascularization (courtesy of Michael Hare); (C) corneal wrinkling (courtesy of Russell Lowe, Bausch & Lomb Slide Library); (D) corneal oedema, in the form of central corneal clouding (courtesy of Patrick Caroline, Bausch & Lomb Slide Library).

Figure 12  Change in visual acuity 173 ± 132 days after visiting the hospital with a corneal infiltrative event, compared with visual acuity prior to attending the hospital. After Efron and Morgan.57
Figure 13  Relation between visual acuity (logMAR) and the degree of lens deposition (Rudko classification). Data for high contrast acuity are given by the open circles and dashed line and data for low contrast acuity are given by the closed circles and solid line. After Gellatly and colleagues.\textsuperscript{62}

Figure 14  Classification of contact lens discomfort. After Nichols and colleagues.\textsuperscript{70}

Figure 15  Summary of the management strategies for contact lens discomfort. After Nichols and colleagues.\textsuperscript{70}

Figure 16  Assessing the physical relationship between the cornea and a soft contact lens using ultra-high resolution anterior eye optical coherence tomography (Courtesy of Jianhua (Jay) Wang).

Figure 17  Fluorescein used to assess lens fit. In this image, a spherical back surface rigid lens is fitted to an eye with high corneal astigmatism. Harsh bearing is observed along the horizontal (flatter) meridian and the lens displays poor centration (Courtesy of Richard Lindsay).

Figure 18  Reasons for lapsing from contact lens wear, as reported in surveys of lapsed lens wearers reported by Pritchard and colleagues\textsuperscript{88} in 1999 (A) and Dumbleton and colleagues\textsuperscript{89} in 2013 (B).

Figure 19  Vending machine for contact lenses.
CXO artist to redraw this figure

- More frequently than every 6 months: 3%
- Every 6 months: 33%
- Every year: 44%
- Every 2 years: 15%
- Every 3 years: 1%
- Less frequently: 2%
- Don’t know: 1%
CXO artist to redraw this figure

- **Annually**: 1%
- **Monthly**: 35%
- **Daily**: 62%
- **1-2 weekly**: 2%
CXO ARTIST TO REDRAW (WITHOUT GRID LINES)

![Graph showing annual progression (D) against baseline age.](image-url)
CXO artist to redraw this figure
Soft lenses: presbyopic fits

- Monovision
- Multifocal
CXO artist to redraw this figure
CXO artist to redraw this figure

- Contact Lens
  - Material e.g. Lubricity Water Content
  - Design e.g. Edge Base Curve
  - Fit & Wear e.g. Lens interaction Modality
  - Lens Care e.g. Solution Chemistry Care Regimen

- Environment
  - Inherent Patient Factors e.g. Age/Gender Ocular/Systemic Disease
  - Modifiable Patient Factors e.g. Medication Compliance
  - Ocular Environment e.g. Lipid/Tear Stability Blink
  - External Environment e.g. Humidity Air Quality
CXO artist to redraw this figure
Contact lens
Epithelium
Stroma
Pre-lens tear film
Post-lens tear film
Note to graphic artist: Please redraft Figures 19A and 19B in the same format/style, as they will be set together in the published manuscript.
Note to graphic artist: Please redraft Figures 19A and 19B in the same format/style, as they will be set together in the published manuscript.